(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 August 2013 (15.08.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/119473 A1

(51) International Patent Classification:
H04W 16/14 (2009.01) *H04W 72/12* (2009.01)
H04W 72/08 (2009.01) *H04W 88/06* (2009.01)

(21) International Application Number:
PCT/US2013/024458

(22) International Filing Date:
1 February 2013 (01.02.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/596,625 8 February 2012 (08.02.2012) US
13/756,472 31 January 2013 (31.01.2013) US

(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; ATTN: International IP Administration, 5775 Morehouse Drive, San Diego, California 92121 (US).

(72) Inventor: **WANG, Jibing**; 5775 Morehouse Drive, San Diego, California 92121 (US).

(74) Agent: **LENKIN, Alan M.**; Seyfarth Shaw LLP, Suite 3500, 2029 Century Park East, Los Angeles, California 90067 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: MULTI-RADIO COEXISTENCE

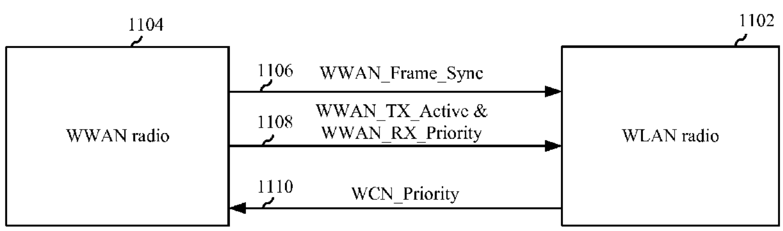

FIG. 11

(57) Abstract: In a multi-radio user equipment (UE) for wireless communication, potential interference between the individual radios may be managed through the use of configurable logical connections between the radios. The connections send signals among the radios to indicate when a particular radio is active. The connections may be configured to indicate different activity types among the radios based on the operating conditions of the radios.

WO 2013/119473 A1

MULTI-RADIO COEXISTENCE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is related to U.S. provisional patent application no. 61/596,625, filed February 8, 2012 in the name of WANG, the disclosure of which is expressly incorporated herein by reference in its entirety.

BACKGROUND

Field

[0002] The present description is related, generally, to multi-radio techniques and, more specifically, to coexistence techniques for multi-radio devices.

BACKGROUND

[0003] Wireless communication systems are widely deployed to provide various types of communication content such as voice, data, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (e.g., bandwidth and transmit power). Examples of such multiple access systems include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, 3GPP Long Term Evolution (LTE) systems, and orthogonal frequency division multiple access (OFDMA) systems.

[0004] Generally, a wireless multiple-access communication system can simultaneously support communication for multiple wireless terminals. Each terminal communicates with one or more base stations via transmissions on the forward and reverse links. The forward link (or downlink) refers to the communication link from the base stations to the terminals, and the reverse link (or uplink) refers to the communication link from the terminals to the base stations. This communication link may be established via a single-in-single-out, multiple-in-single-out or a multiple-in-multiple out (MIMO) system.

[0005] Some conventional advanced devices include multiple radios for transmitting/receiving using different Radio Access Technologies (RATs). Examples of RATs include, e.g., Universal Mobile Telecommunications System (UMTS), Global System for Mobile Communications (GSM), cdma2000, WiMAX, WLAN (e.g., WiFi), Bluetooth, LTE, and the like.

[0006] An example mobile device includes an LTE User Equipment (UE), such as a fourth generation (4G) mobile phone. Such 4G phone may include various radios to provide a variety of functions for the user. For purposes of this example, the 4G phone includes an LTE radio for voice and data, an IEEE 802.11 (WiFi) radio, a Global Positioning System (GPS) radio, and a Bluetooth radio, where two of the above or all four may operate simultaneously. While the different radios provide useful functionalities for the phone, their inclusion in a single device gives rise to coexistence issues. Specifically, operation of one radio may in some cases interfere with operation of another radio through radiative, conductive, resource collision, and/or other interference mechanisms. Coexistence issues include such interference.

[0007] This is especially true for the LTE uplink channel, which is adjacent to the Industrial Scientific and Medical (ISM) band and may cause interference therewith. It is noted that Bluetooth and some Wireless LAN (WLAN) channels fall within the ISM band. In some instances, a Bluetooth error rate can become unacceptable when LTE is active in some channels of Band 7 or even Band 40 for some Bluetooth channel conditions. Even though there is no significant degradation to LTE, simultaneous operation with Bluetooth can result in disruption in voice services terminating in a Bluetooth headset. Such disruption may be unacceptable to the consumer. A similar issue exists when LTE transmissions interfere with GPS. Currently, there is no mechanism that can solve this issue since LTE by itself does not experience any degradation

[0008] With reference specifically to LTE, it is noted that a UE communicates with an evolved NodeB (eNB; e.g., a base station for a wireless communications network) to inform the eNB of interference seen by the UE on the downlink. Furthermore, the eNB may be able to estimate interference at the UE using a downlink error rate. In some instances, the eNB and the UE can cooperate to find a solution that reduces interference at the UE, even interference due to radios within the UE itself. However, in conventional LTE, the interference estimates regarding the downlink may not be adequate to comprehensively address interference.

[0009] In one instance, an LTE uplink signal interferes with a Bluetooth signal or WLAN signal. However, such interference is not reflected in the downlink measurement reports at the eNB. As a result, unilateral action on the part of the UE (e.g., moving the uplink signal to a different channel) may be thwarted by the eNB, which is not aware of the uplink coexistence issue and seeks to undo the unilateral action. For instance, even if the UE re-establishes the connection on a different frequency channel, the network can still handover the UE back to the original frequency channel that was corrupted by the in-device interference. This is a likely scenario because the desired signal strength on the corrupted channel may sometimes be higher than reflected in the measurement reports of the new channel based on Reference Signal Received Power (RSRP) to the eNB. Hence, a ping-pong effect of being transferred back and forth between the corrupted channel and the desired channel can happen if the eNB uses RSRP reports to make handover decisions.

[0010] Other unilateral action on the part of the UE, such as simply stopping uplink communications without coordination of the eNB may cause power loop malfunctions at the eNB. Additional issues that exist in conventional LTE include a general lack of ability on the part of the UE to suggest desired configurations as an alternative to configurations that have coexistence issues. For at least these reasons, uplink coexistence issues at the UE may remain unresolved for a long time period, degrading performance and efficiency for other radios of the UE.

SUMMARY

[0011] Offered is a method for wireless communication. The method includes configuring a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio. The method also includes exchanging, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio. The method further includes adjusting communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

[0012] Offered is an apparatus configured for wireless communication. The apparatus includes means for configuring a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio. The apparatus also includes means for exchanging, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio. The apparatus further includes means for adjusting communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

[0013] Offered is a computer program product configured for wireless communication. The computer program product includes a computer-readable medium having non-transitory program code recorded thereon. The non-transitory program code includes program code to configure a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio. The non-transitory program code also includes program code to exchange, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio. The non-transitory program code further includes program code to adjust communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

[0014] Offered is an apparatus configured for wireless communication. The apparatus includes a memory and a processor(s) coupled to the memory. The processor(s) is configured to configure a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio. The processor(s) is also configured to exchange, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio. The processor(s) is further configured to adjust communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

[0015] Additional features and advantages of the disclosure will be described below. It should be appreciated by those skilled in the art that this disclosure may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the teachings of the disclosure as set forth in the appended claims. The novel features, which are believed to be characteristic of the disclosure, both as to its organization and method of operation, together with further objects and advantages, will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The features, nature, and advantages of the present disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout.

[0017] FIGURE 1 illustrates a multiple access wireless communication system according to one aspect.

[0018] FIGURE 2 is a block diagram of a communication system according to one aspect.

[0019] FIGURE 3 illustrates an exemplary frame structure in downlink Long Term Evolution (LTE) communications.

[0020] FIGURE 4 is a block diagram conceptually illustrating an exemplary frame structure in uplink Long Term Evolution (LTE) communications.

[0021] FIGURE 5 illustrates an example wireless communication environment.

[0022] FIGURE 6 is a block diagram of an example design for a multi-radio wireless device.

[0023] FIGURE 7 is graph showing respective potential collisions between seven example radios in a given decision period.

[0024] FIGURE 8 is a diagram showing operation of an example Coexistence Manager (CxM) over time.

[0025] FIGURE 9 is a block diagram illustrating adjacent frequency bands.

[0026] FIGURE 10 is a block diagram of a system for providing support within a wireless communication environment for multi-radio coexistence management according to one aspect of the present disclosure.

[0027] FIGURE 11 illustrates a coexistence interface for TDD mode according to one aspect of the present disclosure.

[0028] FIGURE 12 illustrates a coexistence interface for FDD mode according to one aspect of the present disclosure.

[0029] FIGURE 13 illustrates a coexistence interface for a multiple radio configuration according to one aspect of the present disclosure.

[0030] FIGURE 14 is a block diagram illustrating a method for mitigating interference according to one aspect of the present disclosure.

[0031] FIGURE 15 is a diagram illustrating an example of a hardware implementation for an apparatus employing components for mitigating interference.

DETAILED DESCRIPTION

[0032] Various aspects of the disclosure provide techniques to mitigate coexistence issues in multi-radio devices, where significant in-device coexistence problems can exist between, e.g., the LTE and Industrial Scientific and Medical (ISM) bands (e.g., for BT/WLAN). Coexistence problems may also exist between radios of the same radio access technology (RAT). For example, multiple WLAN radios may potentially experience interference when operating concurrently. To reduce interference from such operation the radios of the same RAT may be controlled to operate in different frequency ranges.

[0033] The techniques described herein can be used for various wireless communication networks such as Code Division Multiple Access (CDMA) networks, Time Division Multiple Access (TDMA) networks, Frequency Division Multiple Access (FDMA) networks, Orthogonal FDMA (OFDMA) networks, Single-Carrier FDMA (SC-FDMA) networks, etc. The terms “networks” and “systems” are often used interchangeably. A CDMA network can implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband-CDMA (W-CDMA) and Low Chip Rate (LCR). cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network can implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network can implement a radio technology such as Evolved UTRA (E-UTRA), IEEE 802.11, IEEE 802.16, IEEE 802.20, Flash-OFDM®, etc. UTRA, E-UTRA, and GSM are part of Universal Mobile Telecommunication System (UMTS). Long Term Evolution (LTE) is an upcoming release of UMTS that uses E-UTRA. UTRA, E-UTRA, GSM, UMTS and LTE are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). CDMA2000 is described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). These various radio technologies and standards are known in the art. For clarity, certain aspects of the techniques are described below for LTE, and LTE terminology is used in portions of the description below.

[0034] Single carrier frequency division multiple access (SC-FDMA), which utilizes single carrier modulation and frequency domain equalization is a technique that can be utilized with various aspects described herein. SC-FDMA has similar performance and essentially the same overall complexity as those of an OFDMA system. SC-FDMA signal has lower peak-to-average power ratio (PAPR) because of its inherent single carrier structure. SC-FDMA has drawn great attention, especially in the uplink communications where lower PAPR greatly benefits the mobile terminal in terms of transmit power efficiency. It is currently a working assumption for an uplink multiple access scheme in 3GPP Long Term Evolution (LTE), or Evolved UTRA.

[0035] Referring to FIGURE 1, a multiple access wireless communication system according to one aspect is illustrated. An evolved Node B 100 (eNB) includes a computer 115 that has processing resources and memory resources to manage the LTE communications by allocating resources and parameters, granting/denying requests from user equipment, and/or the like. The eNB 100 also has multiple antenna groups, one group including antenna 104 and antenna 106, another group including antenna 108 and antenna 110, and an additional group including antenna 112 and antenna 114. In FIGURE 1, only two antennas are shown for each antenna group, however, more or fewer antennas can be utilized for each antenna group. A User Equipment (UE) 116 (also referred to as an Access Terminal (AT)) is in communication with antennas 112 and 114, while antennas 112 and 114 transmit information to the UE 116 over an uplink (UL) 188. The UE 122 is in communication with antennas 106 and 108, while antennas 106 and 108 transmit information to the UE 122 over a downlink (DL) 116 and receive information from the UE 122 over an uplink 114. In a frequency division duplex (FDD) system, communication links 118, 120, 124 and 126 can use different frequencies for communication. For example, the downlink 120 can use a different frequency than used by the uplink 118.

[0036] Each group of antennas and/or the area in which they are designed to communicate is often referred to as a sector of the eNB. In this aspect, respective antenna groups are designed to communicate to UEs in a sector of the areas covered by the eNB 100.

[0037] In communication over the downlinks 120 and 126, the transmitting antennas of the eNB 100 utilize beamforming to improve the signal-to-noise ratio of the uplinks for the different UEs 116 and 122. Also, an eNB using beamforming to transmit to UEs scattered randomly through its coverage causes less interference to UEs in neighboring cells than a UE transmitting through a single antenna to all its UEs.

[0038] An eNB can be a fixed station used for communicating with the terminals and can also be referred to as an access point, base station, or some other terminology. A UE can also be called an access terminal, a wireless communication device, terminal, or some other terminology.

[0039] FIGURE 2 is a block diagram of an aspect of a transmitter system 210 (also known as an eNB) and a receiver system 250 (also known as a UE) in a MIMO system 200. In some instances, both a UE and an eNB each have a transceiver that includes a transmitter system and a receiver system. At the transmitter system 210, traffic data for a number of data streams is provided from a data source 211 to a transmit (TX) data processor 214.

[0040] A MIMO system employs multiple (NT) transmit antennas and multiple (NR) receive antennas for data transmission. A MIMO channel formed by the NT transmit and NR receive antennas may be decomposed into NS independent channels, which are also referred to as spatial channels, wherein $NS \leq \min\{NT, NR\}$. Each of the NS independent channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., higher throughput and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0041] A MIMO system supports time division duplex (TDD) and frequency division duplex (FDD) systems. In a TDD system, the uplink and downlink transmissions are on the same frequency region so that the reciprocity principle allows the estimation of the downlink channel from the uplink channel. This enables the eNB to extract transmit beamforming gain on the downlink when multiple antennas are available at the eNB.

[0042] In an aspect, each data stream is transmitted over a respective transmit antenna. The TX data processor 214 formats, codes, and interleaves the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.

[0043] The coded data for each data stream can be multiplexed with pilot data using OFDM techniques. The pilot data is a known data pattern processed in a known manner and can be used at the receiver system to estimate the channel response. The multiplexed pilot and coded data for each data stream is then modulated (e.g., symbol mapped) based on a particular modulation scheme (e.g., BPSK, QPSK, M-PSK, or M-QAM) selected for that data stream to provide modulation symbols. The data rate, coding, and modulation for each data stream can be determined by instructions performed by a processor 230 operating with a memory 232.

[0044] The modulation symbols for respective data streams are then provided to a TX MIMO processor 220, which can further process the modulation symbols (e.g., for OFDM). The TX MIMO processor 220 then provides NT modulation symbol streams to NT transmitters (TMTR) 222a through 222t. In certain aspects, the TX MIMO processor 220 applies beamforming weights to the symbols of the data streams and to the antenna from which the symbol is being transmitted.

[0045] Each transmitter 222 receives and processes a respective symbol stream to provide one or more analog signals, and further conditions (e.g., amplifies, filters, and upconverts) the analog signals to provide a modulated signal suitable for transmission over the MIMO channel. NT modulated signals from the transmitters 222a through 222t are then transmitted from NT antennas 224a through 224t, respectively.

[0046] At a receiver system 250, the transmitted modulated signals are received by NR antennas 252a through 252r and the received signal from each antenna 252 is provided to a respective receiver (RCVR) 254a through 254r. Each receiver 254 conditions (e.g., filters, amplifies, and downconverts) a respective received signal, digitizes the conditioned signal to provide samples, and further processes the samples to provide a corresponding "received" symbol stream.

[0047] An RX data processor 260 then receives and processes the NR received symbol streams from NR receivers 254 based on a particular receiver processing technique to provide NR "detected" symbol streams. The RX data processor 260 then demodulates, deinterleaves, and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by the RX data processor 260 is complementary to the processing performed by the TX MIMO processor 220 and the TX data processor 214 at the transmitter system 210.

[0048] A processor 270 (operating with a memory 272) periodically determines which pre-coding matrix to use (discussed below). The processor 270 formulates an uplink message having a matrix index portion and a rank value portion.

[0049] The uplink message can include various types of information regarding the communication link and/or the received data stream. The uplink message is then processed by a TX data processor 238, which also receives traffic data for a number of data streams from a data source 236, modulated by a modulator 280, conditioned by transmitters 254a through 254r, and transmitted back to the transmitter system 210.

[0050] At the transmitter system 210, the modulated signals from the receiver system 250 are received by antennas 224, conditioned by receivers 222, demodulated by a demodulator 240, and processed by an RX data processor 242 to extract the uplink message transmitted by the receiver system 250. The processor 230 then determines which pre-coding matrix to use for determining the beamforming weights, then processes the extracted message.

[0051] FIGURE 3 is a block diagram conceptually illustrating an exemplary frame structure in downlink Long Term Evolution (LTE) communications. The transmission timeline for the downlink may be partitioned into units of radio frames. Each radio frame may have a predetermined duration (e.g., 10 milliseconds (ms)) and may be partitioned into 10 subframes with indices of 0 through 9. Each subframe may include two slots. Each radio frame may thus include 20 slots with indices of 0 through 19. Each slot may include L symbol periods, e.g., 7 symbol periods for a normal cyclic prefix (as shown in FIGURE 3) or 6 symbol periods for an extended cyclic prefix. The 2L symbol periods in each subframe may be assigned indices of 0 through 2L–1. The available time frequency resources may be partitioned into resource blocks. Each resource block may cover N subcarriers (e.g., 11 subcarriers) in one slot.

[0052] In LTE, an eNB may send a Primary Synchronization Signal (PSS) and a Secondary Synchronization Signal (SSS) for each cell in the eNB. The PSS and SSS may be sent in symbol periods 6 and 5, respectively, in each of subframes 0 and 5 of each radio frame with the normal cyclic prefix, as shown in FIGURE 3. The synchronization signals may be used by UEs for cell detection and acquisition. The eNB may send a Physical Broadcast Channel (PBCH) in symbol periods 0 to 3 in slot 1 of subframe 0. The PBCH may carry certain system information.

[0053] The eNB may send a Cell-specific Reference Signal (CRS) for each cell in the eNB. The CRS may be sent in symbols 0, 1, and 4 of each slot in case of the normal cyclic prefix, and in symbols 0, 1, and 3 of each slot in case of the extended cyclic prefix. The CRS may be used by UEs for coherent demodulation of physical channels, timing and frequency tracking, Radio Link Monitoring (RLM), Reference Signal Received Power (RSRP), and Reference Signal Received Quality (RSRQ) measurements, etc.

[0054] The eNB may send a Physical Control Format Indicator Channel (PCFICH) in the first symbol period of each subframe, as seen in FIGURE 3. The PCFICH may convey the number of symbol periods (M) used for control channels, where M may be equal to 1, 2 or 3 and may change from subframe to subframe. M may also be equal to 4 for a small system bandwidth, e.g., with less than 10 resource blocks. In the example shown in FIGURE 3, M=3. The eNB may send a Physical HARQ Indicator Channel (PHICH) and a Physical Downlink Control Channel (PDCCH) in the first M symbol periods of each subframe. The PDCCH and PHICH are also included in the first three symbol periods in the example shown in FIGURE 3. The PHICH may carry information to support Hybrid Automatic Repeat Request (HARQ). The PDCCH may carry information on resource allocation for UEs and control information for downlink channels. The eNB may send a Physical Downlink Shared Channel (PDSCH) in the remaining symbol periods of each subframe. The PDSCH may carry data for UEs scheduled for data transmission on the downlink. The various signals and channels in LTE are described in 3GPP TS 36.211, entitled "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation," which is publicly available.

[0055] The eNB may send the PSS, SSS and PBCH in the center 1.08 MHz of the system bandwidth used by the eNB. The eNB may send the PCFICH and PHICH across the entire system bandwidth in each symbol period in which these channels are sent. The eNB may send the PDCCH to groups of UEs in certain portions of the system bandwidth. The eNB may send the PDSCH to specific UEs in specific portions of the system bandwidth. The eNB may send the PSS, SSS, PBCH, PCFICH and PHICH in a broadcast manner to all UEs, may send the PDCCH in a unicast manner to specific UEs, and may also send the PDSCH in a unicast manner to specific UEs.

[0056] A number of resource elements may be available in each symbol period. Each resource element may cover one subcarrier in one symbol period and may be used to send one modulation symbol, which may be a real or complex value. Resource elements not used for a reference signal in each symbol period may be arranged into resource element groups (REGs). Each REG may include four resource elements in one symbol period. The PCFICH may occupy four REGs, which may be spaced approximately equally across frequency, in symbol period 0. The PHICH may occupy three REGs, which may be spread across frequency, in one or more configurable symbol periods. For example, the three REGs for the PHICH may all belong in symbol period 0 or may be spread in symbol periods 0, 1 and 2. The PDCCH may occupy 9, 18, 32 or 64 REGs, which may be selected from the available REGs, in the first M symbol periods. Only certain combinations of REGs may be allowed for the PDCCH.

[0057] A UE may know the specific REGs used for the PHICH and the PCFICH. The UE may search different combinations of REGs for the PDCCH. The number of combinations to search is typically less than the number of allowed combinations for the PDCCH. An eNB may send the PDCCH to the UE in any of the combinations that the UE will search.

[0058] FIGURE 4 is a block diagram conceptually illustrating an exemplary frame structure in uplink Long Term Evolution (LTE) communications. The available Resource Blocks (RBs) for the uplink may be partitioned into a data section and a control section. The control section may be formed at the two edges of the system bandwidth and may have a configurable size. The resource blocks in the control section may be assigned to UEs for transmission of control information. The data section may include all resource blocks not included in the control section. The design in FIGURE 4 results in the data section including contiguous subcarriers, which may allow a single UE to be assigned all of the contiguous subcarriers in the data section.

[0059] A UE may be assigned resource blocks in the control section to transmit control information to an eNB. The UE may also be assigned resource blocks in the data section to transmit data to the eNodeB. The UE may transmit control information in a Physical Uplink Control Channel (PUCCH) on the assigned resource blocks in the control section. The UE may transmit only data or both data and control information in a Physical Uplink Shared Channel (PUSCH) on the assigned resource blocks in the data section. An uplink transmission may span both slots of a subframe and may hop across frequency as shown in FIGURE 4.

[0060] The PSS, SSS, CRS, PBCH, PUCCH and PUSCH in LTE are described in 3GPP TS 36.211, entitled “Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation,” which is publicly available.

[0061] In an aspect, described herein are systems and methods for providing support within a wireless communication environment, such as a 3GPP LTE environment or the like, to facilitate multi-radio coexistence solutions.

[0062] Referring now to FIGURE 5, illustrated is an example wireless communication environment 500 in which various aspects described herein can function. The wireless communication environment 500 can include a wireless device 510, which can be capable of communicating with multiple communication systems. These systems can include, for example, one or more cellular systems 520 and/or 530, one or more WLAN systems 540 and/or 550, one or more wireless personal area network (WPAN) systems 560, one or more broadcast systems 570, one or more satellite positioning systems 580, other systems not shown in FIGURE 5, or any combination thereof. It should be appreciated that in the following description the terms “network” and “system” are often used interchangeably.

[0063] The cellular systems 520 and 530 can each be a CDMA, TDMA, FDMA, OFDMA, Single Carrier FDMA (SC-FDMA), or other suitable system. A CDMA system can implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. Moreover, cdma2000 covers IS-2000 (CDMA2000 1X), IS-95 and IS-856 (HRPD) standards. A TDMA system can implement a radio technology such as Global System for Mobile Communications (GSM), Digital Advanced Mobile Phone System (D-AMPS), etc. An OFDMA system can implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM®, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). cdma2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). In an aspect, the cellular system 520 can include a number of base stations 522, which can support bi-directional communication for wireless devices within their coverage. Similarly, the cellular system 530 can include a number of base stations 532 that can support bi-directional communication for wireless devices within their coverage.

[0064] WLAN systems 540 and 550 can respectively implement radio technologies such as IEEE 802.11 (WiFi), Hiperlan, etc. The WLAN system 540 can include one or more access points 542 that can support bi-directional communication. Similarly, the WLAN system 550 can include one or more access points 552 that can support bi-directional communication. The WPAN system 560 can implement a radio technology such as Bluetooth (BT), IEEE 802.15, etc. Further, the WPAN system 560 can support bi-directional communication for various devices such as wireless device 510, a headset 562, a computer 564, a mouse 566, or the like.

[0065] The broadcast system 570 can be a television (TV) broadcast system, a frequency modulation (FM) broadcast system, a digital broadcast system, etc. A digital broadcast system can implement a radio technology such as MediaFLO™, Digital Video Broadcasting for Handhelds (DVB-H), Integrated Services Digital Broadcasting for Terrestrial Television Broadcasting (ISDB-T), or the like. Further, the broadcast system 570 can include one or more broadcast stations 572 that can support one-way communication.

[0066] The satellite positioning system 580 can be the United States Global Positioning System (GPS), the European Galileo system, the Russian GLONASS system, the Quasi-Zenith Satellite System (QZSS) over Japan, the Indian Regional Navigational Satellite System (IRNSS) over India, the Beidou system over China, and/or any other suitable system. Further, the satellite positioning system 580 can include a number of satellites 582 that transmit signals for position determination.

[0067] In an aspect, the wireless device 510 can be stationary or mobile and can also be referred to as a user equipment (UE), a mobile station, a mobile equipment, a terminal, an access terminal, a subscriber unit, a station, etc. The wireless device 510 can be cellular phone, a personal digital assistance (PDA), a wireless modem, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, etc. In addition, a wireless device 510 can engage in two-way communication with the cellular system 520 and/or 530, the WLAN system 540 and/or 550, devices with the WPAN system 560, and/or any other suitable systems(s) and/or devices(s). The wireless device 510 can additionally or alternatively receive signals from the broadcast system 570 and/or satellite positioning system 580. In general, it can be appreciated that the wireless device 510 can communicate with any number of systems at any given moment. Also, the wireless device 510 may experience coexistence issues among various ones of its constituent radio devices that operate at the same time. Accordingly, device 510 includes a coexistence manager (CxM, not shown) that has a functional module to detect and mitigate coexistence issues, as explained further below.

[0068] Turning next to FIGURE 6, a block diagram is provided that illustrates an example design for a multi-radio wireless device 600 and may be used as an implementation of the radio or wireless device 510 of FIGURE 5. As FIGURE 6 illustrates, the wireless device 600 can include N radios 620a through 620n, which can be coupled to N antennas 610a through 610n, respectively, where N can be any integer value. It should be appreciated, however, that respective radios 620 can be coupled to any number of antennas 610 and that multiple radios 620 can also share a given antenna 610.

[0069] In general, a radio 620 can be a unit that radiates or emits energy in an electromagnetic spectrum, receives energy in an electromagnetic spectrum, or generates energy that propagates via conductive means. By way of example, a radio 620 can be a unit that transmits a signal to a system or a device or a unit that receives signals from a system or device. Accordingly, it can be appreciated that a radio 620 can be utilized to support wireless communication. In another example, a radio 620 can also be a unit (e.g., a screen on a computer, a circuit board, etc.) that emits noise, which can impact the performance of other radios. Accordingly, it can be further appreciated that a radio 620 can also be a unit that emits noise and interference without supporting wireless communication.

[0070] In an aspect, respective radios 620 can support communication with one or more systems. Multiple radios 620 can additionally or alternatively be used for a given system, e.g., to transmit or receive on different frequency bands (e.g., cellular and PCS bands).

[0071] In another aspect, a digital processor 630 can be coupled to radios 620a through 620n and can perform various functions, such as processing for data being transmitted or received via the radios 620. The processing for each radio 620 can be dependent on the radio technology supported by that radio and can include encryption, encoding, modulation, etc., for a transmitter; demodulation, decoding, decryption, etc., for a receiver, or the like. In one example, the digital processor 630 can include a coexistence manager (CxM) 640 that can control operation of the radios 620 in order to improve the performance of the wireless device 600 as generally described herein. The coexistence manager 640 can have access to a database 644, which can store information used to control the operation of the radios 620. As explained further below, the coexistence manager 640 can be adapted for a variety of techniques to decrease interference between the radios. In one example, the coexistence manager 640 requests a measurement gap pattern or DRX cycle that allows an ISM radio to communicate during periods of LTE inactivity.

[0072] For simplicity, digital processor 630 is shown in FIGURE 6 as a single processor. However, it should be appreciated that the digital processor 630 can include any number of processors, controllers, memories, etc. In one example, a controller/processor 650 can direct the operation of various units within the wireless device 600. Additionally or alternatively, a memory 652 can store program codes and data for the wireless device 600. The digital processor 630, controller/processor 650, and memory 652 can be implemented on one or more integrated circuits (ICs), application specific integrated circuits (ASICs), etc. By way of specific, non-limiting example, the digital processor 630 can be implemented on a Mobile Station Modem (MSM) ASIC.

[0073] In an aspect, the coexistence manager 640 can manage operation of respective radios 620 utilized by wireless device 600 in order to avoid interference and/or other performance degradation associated with collisions between respective radios 620. coexistence manager 640 may perform one or more processes, such as those illustrated in FIGURE 11. By way of further illustration, a graph 700 in FIGURE 7 represents respective potential collisions between seven example radios in a given decision period. In the example shown in graph 700, the seven radios include a WLAN transmitter (Tw), an LTE transmitter (Tl), an FM transmitter (Tf), a GSM/WCDMA transmitter (Tc/Tw), an LTE receiver (Rl), a Bluetooth receiver (Rb), and a GPS receiver (Rg). The four transmitters are represented by four nodes on the left side of the graph 700. The four receivers are represented by three nodes on the right side of the graph 700.

[0074] A potential collision between a transmitter and a receiver is represented on the graph 700 by a branch connecting the node for the transmitter and the node for the receiver. Accordingly, in the example shown in the graph 700, collisions may exist between (1) the WLAN transmitter (Tw) and the Bluetooth receiver (Rb); (2) the LTE transmitter (Tl) and the Bluetooth receiver (Rb); (3) the WLAN transmitter (Tw) and the LTE receiver (Rl); (4) the FM transmitter (Tf) and the GPS receiver (Rg); (5) a WLAN transmitter (Tw), a GSM/WCDMA transmitter (Tc/Tw), and a GPS receiver (Rg).

[0075] In one aspect, an example coexistence manager 640 can operate in time in a manner such as that shown by diagram 800 in FIGURE 8. As diagram 800 illustrates, a timeline for coexistence manager operation can be divided into Decision Units (DUs), which can be any suitable uniform or non-uniform length (e.g., 100 μs) where notifications are processed, and a response phase (e.g., 20 μs) where commands are provided to various radios 620 and/or other operations are performed based on actions taken in the evaluation phase. In one example, the timeline shown in the diagram 800 can have a latency parameter defined by a worst case operation of the timeline, e.g., the timing of a response in the case that a notification is obtained from a given radio immediately following termination of the notification phase in a given DU.

[0076] As shown in FIGURE 9, Long Term Evolution (LTE) in band 7 (for frequency division duplex (FDD) uplink), band 40 (for time division duplex (TDD) communication), and band 38 (for TDD downlink) is adjacent to the 2.4 GHz Industrial Scientific and Medical (ISM) band used by Bluetooth (BT) and Wireless Local Area Network (WLAN) technologies. Frequency planning for these bands is such that there is limited or no guard band permitting traditional filtering solutions to avoid interference at adjacent frequencies. For example, a 20 MHz guard band exists between ISM and band 7, but no guard band exists between ISM and band 40.

[0077] To be compliant with appropriate standards, communication devices operating over a particular band are to be operable over the entire specified frequency range. For example, in order to be LTE compliant, a mobile station/user equipment should be able to communicate across the entirety of both band 40 (2300-2400 MHz) and band 7 (2500-2570 MHz) as defined by the 3rd Generation Partnership Project (3GPP). Without a sufficient guard band, devices employ filters that overlap into other bands causing band interference. Because band 40 filters are 100 MHz wide to cover the entire band, the rollover from those filters crosses over into the ISM band causing interference. Similarly, ISM devices that use the entirety of the ISM band (e.g., from 2401 through approximately 2480 MHz) will employ filters that rollover into the neighboring band 40 and band 7 and may cause interference.

[0078] In-device coexistence problems can exist with respect to a UE between resources such as, for example, LTE and ISM bands (e.g., for Bluetooth/WLAN). In current LTE implementations, any interference issues to LTE are reflected in the downlink measurements (e.g., Reference Signal Received Quality (RSRQ) metrics, etc.) reported by a UE and/or the downlink error rate which the eNB can use to make inter-frequency or inter-RAT handoff decisions to, e.g., move LTE to a channel or RAT with no coexistence issues. However, it can be appreciated that these existing techniques will not work if, for example, the LTE uplink is causing interference to Bluetooth/WLAN but the LTE downlink does not see any interference from Bluetooth/WLAN. More particularly, even if the UE autonomously moves itself to another channel on the uplink, the eNB can in some cases handover the UE back to the problematic channel for load balancing purposes. In any case, it can be appreciated that existing techniques do not facilitate use of the bandwidth of the problematic channel in the most efficient way.

[0079] Turning now to FIGURE 10, a block diagram of a system 1000 for providing support within a wireless communication environment for multi-radio coexistence management is illustrated. In an aspect, the system 1000 can include one or more UEs 1010 and/or eNBs 1040, which can engage in uplink and/or downlink communications, and/or any other suitable communication with each other and/or any other entities in the system 1000. In one example, the UE 1010 and/or eNB 1040 can be operable to communicate using a variety resources, including frequency channels and sub-bands, some of which can potentially be colliding with other radio resources (e.g., a broadband radio such as an LTE modem). In another aspect, the system may also include access points and/or external wireless devices (not shown). Thus, the UE 1010 can utilize various techniques for managing coexistence between multiple radios utilized by the UE 1010, as generally described herein.

[0080] To mitigate at least the above shortcomings, the UE 1010 can utilize respective features described herein and illustrated by the system 1000 to facilitate support for multi-radio coexistence within the UE 1010. For example, channel monitoring module 1012 and a coexistence management module 1014 may be provided. The channel monitoring module 1012 monitors for potential coexistence issues between radios. The coexistence management module 1014 executes commands among the coexistence manager 640 and various radios to manage potential interference issues. The various modules 1012-1014 may, in some examples, be implemented as part of a coexistence manager such as the coexistence manager 640 of FIGURE 6. The various modules 1012-1014 and others may be configured to implement the embodiments discussed herein.

[0081] A wireless local area network (WLAN) radio may have several operating modes. In an access point (AP), soft access point (SoftAP), or peer-to-peer (P2P) Group Owner (GO) mode, etc. a WLAN radio may serve data to other devices. In station mode a WLAN radio is being served by an access point or other device. Various methods for coexistence management may be applied depending on the operating mode of a WLAN radio. For example, if a WLAN radio in SoftAP or P2P GO mode encounters coexistence issues, one method of addressing such issues is for the WLAN radio to switch to a different channel to avoid the coexistence issue. If potential interference exists between a WLAN radio and a time-division duplexed (TDD) wireless wide area network (WWAN) radio, the WLAN communication may be fit into gaps between the WWAN transmission or reception. Similarly, when a WLAN radio encounters potential coexistence issues with a TDD-Long Term Evolution (LTE) radio, a Time-Division Synchronous Code Division Multiple Access (TD-SCDMA) radio, or a Global System for Mobile Communications (GSM) radio, WLAN communications may be fit into gaps of those potentially conflicting radios. A WLAN radio in station mode may also hand off to a different access point using a different frequency or band which may result in reduced interference (for example, switching to 2.4 GHz, as supported by most 5 GHz capable access points). A WLAN radio may also handoff to WWAN or to a different network for purposes of data communications by a mobile device in order to reduce interference. For example, if WLAN communications may interfere with a voice call using a Universal Mobile Telecommunications System (UMTS) network, a coexistence manager may route data through a WWAN (UMTS data network) as opposed to WLAN to reduce potential interference. Such a solution may also apply to a 1x Code Division Multiple Access (CDMA) network. WLAN radio communications may also be altered to protect page/measurement operations by a WWAN radio when in idle mode.

[0082] To coordinate operations between different radios to reduce potential interference, a wire or logical interface may be constructed between the radios to indicate relative radio activity and priority. In one aspect, a three-wire interface may be configured between the radios. The interface may include three logical connectors between the radios that may indicate to the individual radios certain operational conditions of the other to reduce potential interference issues. As an example, FIGURE 11 illustrates a coexistence interface for a WWAN radio operating in TDD mode according to one aspect of the present disclosure. As shown in FIGURE 11, a WLAN radio 1102 is connected to a WWAN radio 1104 with three logical connectors. When the radios operate in TDD mode, the connectors may be WWAN_Frame_Sync 1106, WWAN_TX_Active and WWAN_RX_Priority 1108, and WCN_Priority 1110. The WWAN_Frame_Sync connector 1106 may be used to synchronize the TDD configurations of the radios. The WWAN_TX_Active and WWAN_RX_Priority connector 1108 may be used to indicate transmission (TX) activity and/or receive (RX) priority of the radio. For example, a WWAN radio may set the WWAN_TX_Active and WWAN_RX_Priority connector 1108 active to indicate when its operations are priority operations. When the connector 1108 is set, the WLAN radio may alter its communications operations so as to not interfere with the WWAN radio. The WCN_Priority (wireless communication priority) connector 1110 may indicate to the WWAN radio 1104 when another radio (such as the WLAN radio 1102) is engaged in high priority reception so that the WWAN radio 1104 may halt transmit activity that may potentially interfere with the high priority receptions of the WLAN radio.

[0083] A different three-wire interface may be configured for coordinating between the WLAN radio and a frequency division duplexed (FDD) radio, as a frame synch interface may not be used. Such FDD technologies may include LTE, Wideband Code Division Multiple Access (WCDMA), CDMA, and GSM. An example three-wire according to this aspect is shown in FIGURE 12. The WWAN_TX_Active connector 1206 may be used to indicate to the WLAN radio when the WWAN radio is transmitting so the WLAN radio may, during the WWAN transmit times, avoid reception activity that may potentially be interfered with. The WWAN_RX_Priority connector 1208 may be used to indicate when the WWAN is receiving a high priority signal. When the connector 1208 is set, the WLAN radio may alter its transmit activity so as to not interfere with the WWAN radio. The WCN_Priority connector 1210 may indicate to the WWAN radio 1204 when another radio (such as the WLAN radio 1202) is engaged in high priority reception so that the WWAN radio 1204 may halt transmit activity that may potentially interfere with the high priority receptions of the WLAN radio.

[0084] In one aspect the three-wire interface may be physically configured in a fixed manner to connect radios, but the signals carried across the pins may correspond to different radio configurations, such as the respective TDD or FDD configurations of FIGURE 11 or FIGURE 12. In another aspect, the signals carried across the three-wire interface may correspond to a configuration where multiple WWAN radios are available. Such a configuration is shown in FIGURE 13. As shown in figure 13 a WLAN radio 1302 is connected to multiple WWAN radios, illustrated as block 1304. In this configuration each connector 1306 and 1308 from the WWAN radios 1304 to the WLAN radio 1302 corresponds to a single radio access technology (RAT) radio of the WWAN radios 1304. For example, connector WWAN_RAT1_Active 1306 indicates activity of a first RAT WWAN radio while connector WWAN_RAT2_Active 1308 indicates activity of a second RAT WWAN radio. For example, RAT1 may be a GSM radio and RAT2 may be a WCDMA radio. If either connector 1306 or 1308 is active, the WLAN radio may alter its communications operations so as to not interfere with the active WWAN radio. WLAN may react differently with respect to connector 1306 and connector 1308. That is, the WLAN radio may alter its communications in one way in response to activity on connector 1306 and in another way in response to activity on connector 1308 (and potentially in a third way in response to activity on both connectors). The WCN_Priority connector 1310 may operate similarly to connectors 1210 or 1110, that is to indicate to the WWAN radios of a high priority WLAN reception so that the WWAN radios 1304 may halt transmit activity that may potentially interfere with the high priority receptions of the WLAN radio.

[0085] In another aspect connectors 1306, 1308, and 1310 may be even more specialized. For example, in one aspect connector 1306 may be configured as a

GSM_RX_Active connector, indicating an active GSM reception. In another aspect connector 1308 may be configured as a WCDMA_TX_Active connector, indicating an active WCDMA Transmission. In another aspect, if a device is configured with an LTE radio with carrier aggregation, connectors 1306 and 1308 may be configured to indicate activity for individual carrier frequencies for the LTE radio, such as LTE_TX_Active for one carrier and LTE_RX_Active for another carrier. Depending on the configurations of the connectors, the WLAN radio may operate in a manner to reduce potential interference with the radio activity indicated by the connectors.

[0086] The physical protocol of the logical signals in the three-wire interface may change based upon the change of radio conditions (such as FDD/TDD, carrier frequencies, radio states) of multiple radio access technologies. The aggressor(s) (the radio(s) potentially causing the interference) and victim(s) (the radio(s) potentially suffering from the interference) may alter their behavior accordingly based upon the current three-wire protocol in order to reduce the interference.

[0087] Although illustrated as a logical interface, the three-wire interface may also be configured as a software messaging interface, or other combination of hardware, software, and/or firmware. As a result of the signals passed over the interface, the radios of the different radio access technologies (RATs) may alter their behavior to reduce potential interference between the RATs.

[0088] As shown in FIGURE 14 a UE may configure a plurality of logical connections between a first radio of a first RAT and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio, as shown in block 1402. A UE may exchange, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio, as shown in block 1404. The UE may adjust communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections, as shown in block 1406

[0089] FIGURE 15 is a diagram illustrating an example of a hardware implementation for an apparatus 1500 employing a system 1514. The system 1514 may be implemented with a bus architecture, represented generally by a bus 1524. The bus 1524 may include any number of interconnecting buses and bridges depending on the specific application of the system 1514 and the overall design constraints. The bus 1524 links together various circuits including one or more processors and/or hardware modules, represented by a processor 1526, a configuring module 1502, an exchanging module 1504 and an adjusting module 1506, and a computer-readable medium 1528. The bus 1524 may also link various other circuits such as timing sources, peripherals, voltage regulators, and power management circuits, which are well known in the art, and therefore, will not be described any further.

[0090] The apparatus includes the system 1514 coupled to a transceiver 1522. The transceiver 1522 is coupled to one or more antennas 1520. The transceiver 1522 provides a means for communicating with various other apparatus over a transmission medium. The system 1514 includes the processor 1526 coupled to the computer-readable medium 1528. The processor 1526 is responsible for general processing, including the execution of software stored on the computer-readable medium 1528. The software, when executed by the processor 1526, causes the system 1514 to perform the various functions described supra for any particular apparatus. The computer-readable medium 1528 may also be used for storing data that is manipulated by the processor 1526 when executing software. The system 1514 further includes the configuring module 1502 for configuring a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio. The system 1514 further includes the exchanging module 1504 for exchanging, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio. The system 1514 further includes the adjusting module 1506 for adjusting communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections. The modules 1502-1506 may be software modules running in the processor 1526, resident/stored in the computer readable medium 1528, one or more hardware modules coupled to the processor 1526, or some combination thereof. The system 1514 may be a component of the UE 250 and may include the memory 272 and/or the processor 270.

[0091] In one configuration, the apparatus 1500 for wireless communication includes means for configuring. The means may be the configuring module 1502 and/or the system 1514 of the apparatus 1500 configured to perform the functions recited by the means. The means may also include coexistence manager 640, processor 270/630/650/1526, memory 272/652, database 644, and/or computer-readable medium 1528. In another aspect, the aforementioned means may be any module or any apparatus configured to perform the functions recited by the aforementioned means.

[0092] In one configuration, the apparatus 1500 for wireless communication includes means for exchanging. The means may be the exchanging module 1504 and/or the system 1514 of the apparatus 1500 configured to perform the functions recited by the means. The means may also include coexistence manager 640, processor 270/630/650/1526, memory 272/652, database 644, computer-readable medium 1528 and/or connectors 1106, 1108, 1110, 1206, 1208, 1210, 1306, 1308, 1310. In another aspect, the aforementioned means may be any module or any apparatus configured to perform the functions recited by the aforementioned means.

[0093] In one configuration, the apparatus 1500 for wireless communication includes means for adjusting. The means may be the adjusting module 1506 and/or the system 1514 of the apparatus 1500 configured to perform the functions recited by the means. The means may also include coexistence manager 640, processor 270/630/650/1526, memory 272/652, database 644, computer-readable medium 1528, transceiver 254/1522 and/or antennae 252/610/1520. In another aspect, the aforementioned means may be any module or any apparatus configured to perform the functions recited by the aforementioned means.

[0094] The examples above describe aspects implemented in an LTE system. However, the scope of the disclosure is not so limited. Various aspects may be adapted for use with other communication systems, such as those that employ any of a variety of communication protocols including, but not limited to, CDMA systems, TDMA systems, FDMA systems, and OFDMA systems.

[0095] It is understood that the specific order or hierarchy of steps in the processes disclosed is an example of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0096] Those of skill in the art would understand that information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0097] Those of skill would further appreciate that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the aspects disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present disclosure.

[0098] The various illustrative logical blocks, modules, and circuits described in connection with the aspects disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0099] The steps of a method or algorithm described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium is coupled to the processor such the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. The processor and the storage medium may reside in an ASIC. The ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal.

[00100] The previous description of the disclosed aspects is provided to enable any person skilled in the art to make or use the present disclosure. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects without departing from the spirit or scope of the disclosure. Thus, the present disclosure is not intended to be limited to the aspects shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A method of wireless communication, comprising:

configuring a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio;

exchanging, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio; and

adjusting communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

2. The method of claim 1, in which the plurality of logical connections are physical connections.

3. The method of claim 1, in which the plurality of logical connection are software messages.

4. The method of claim 1, in which the first RAT is a wireless wide area network (WWAN) RAT.

5. The method of claim 1, in which the second RAT is a wireless local area network (WLAN) RAT.

6. The method of claim 1, in which adjusting communications comprises at least one of:

communicating with the second RAT during communication gaps of the first RAT;

communicating with the second RAT through a different access point;

handing over data communications from the second RAT to the first RAT; and

protecting communications of the first RAT while the first RAT is in idle mode.

7. The method of claim 1, in which the operating condition of the first RAT is one of a carrier frequency used or a radio state.

8. The method of claim 1, in which the operating condition of the first RAT is one of a frequency division duplex (FDD) mode or time division duplex (TDD) mode.

9. An apparatus configured for wireless communication, comprising:

means for configuring a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio;

means for exchanging, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio; and

means for adjusting communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

10. The apparatus of claim 9, in which the operating condition of the first RAT is one of a frequency division duplex (FDD) mode or time division duplex (TDD) mode.

11. A computer program product configured for wireless communication, the computer program product comprising:

a computer-readable medium having non-transitory program code recorded thereon, the non-transitory program code comprising:

program code to configure a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio;

program code to exchange, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio; and

program code to adjust communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

12. The computer program product of claim 11, in which the operating condition of the first RAT is one of a frequency division duplex (FDD) mode or time division duplex (TDD) mode.

13. An apparatus configured for wireless communication, the apparatus comprising:

a memory; and

at least one processor coupled to the memory, the at least one processor being configured:

to configure a plurality of logical connections between a first radio of a first radio access technology (RAT) and a second radio of a second RAT based on an operating condition of at least one of the first radio or second radio;

to exchange, over the configured logical connections, indications of potentially interfering communications between the first radio and second radio; and

to adjust communications of at least one of the first radio or second radio based on the indications exchanged over the configured logical connections.

14. The apparatus of claim 13, in which the plurality of logical connections are physical connections.

15. The apparatus of claim 13, in which the plurality of logical connection are software messages.

16. The apparatus of claim 13, in which the first RAT is a wireless wide area network (WWAN) RAT.

17. The apparatus of claim 13, in which the second RAT is a wireless local area network (WLAN) RAT.

18. The apparatus of claim 13, in which the at least one processor is further configured to adjust communications by at least one of:

communicating with the second RAT during communication gaps of the first RAT;

communicating with the second RAT through a different access point;

handing over data communications from the second RAT to the first RAT; and

protecting communications of the first RAT while the first RAT is in idle mode.

19. The apparatus of claim 13, in which the operating condition of the first RAT is

one of a carrier frequency used or a radio state.

20. The apparatus of claim 13, in which the operating condition of the first RAT is one of a frequency division duplex (FDD) mode or time division duplex (TDD) mode.

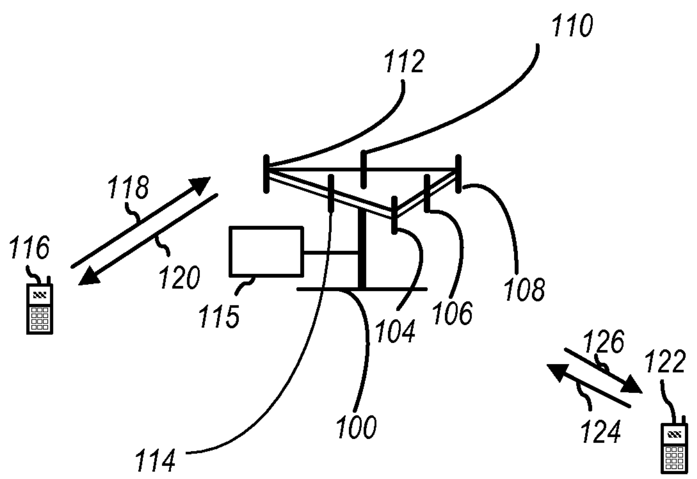
110
112
118
116
120
115
104
106
108
126
122
124
100
114

FIG. 1

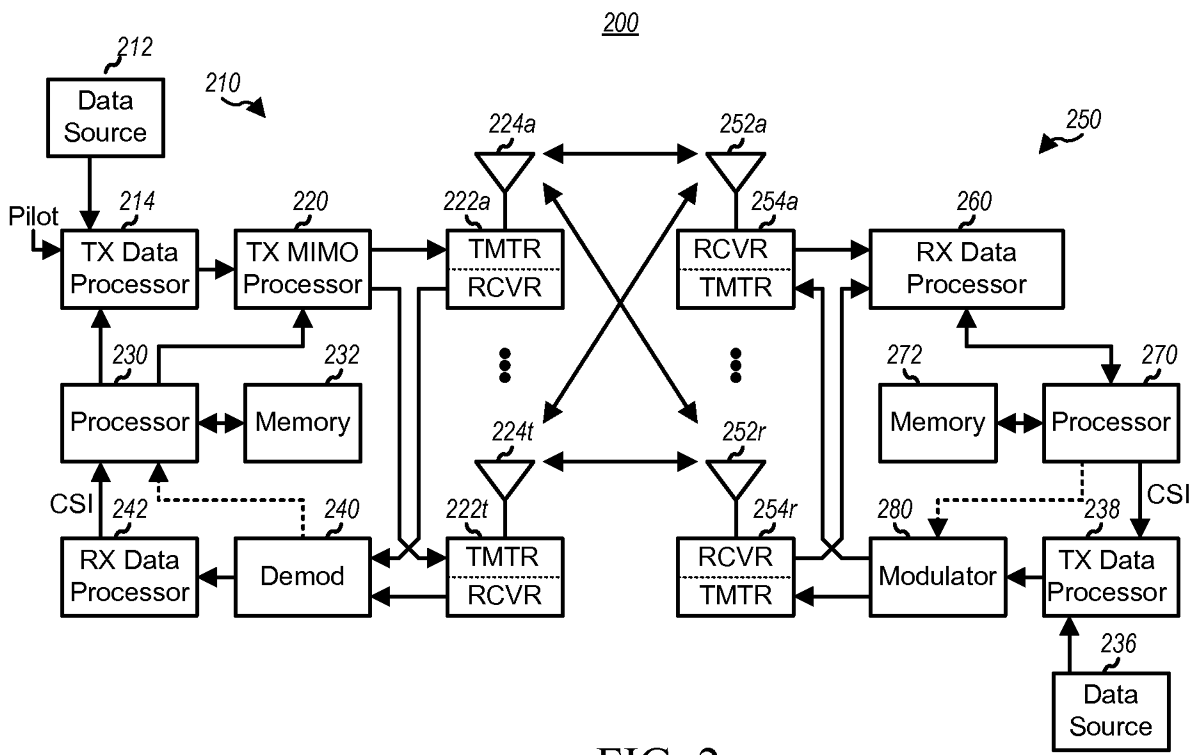
200
212
Data Source
210
224a
252a
250
Pilot
214
220
222a
254a
260
TX Data Processor
TX MIMO Processor
TMTR
RCVR
RCVR
TMTR
RX Data Processor
230
232
272
270
Processor
Memory
Memory
Processor
224t
252r
CSI
242
240
222t
254r
280
238
CSI
RX Data Processor
Demod
TMTR
RCVR
RCVR
TMTR
Modulator
TX Data Processor
236
Data Source

FIG. 2

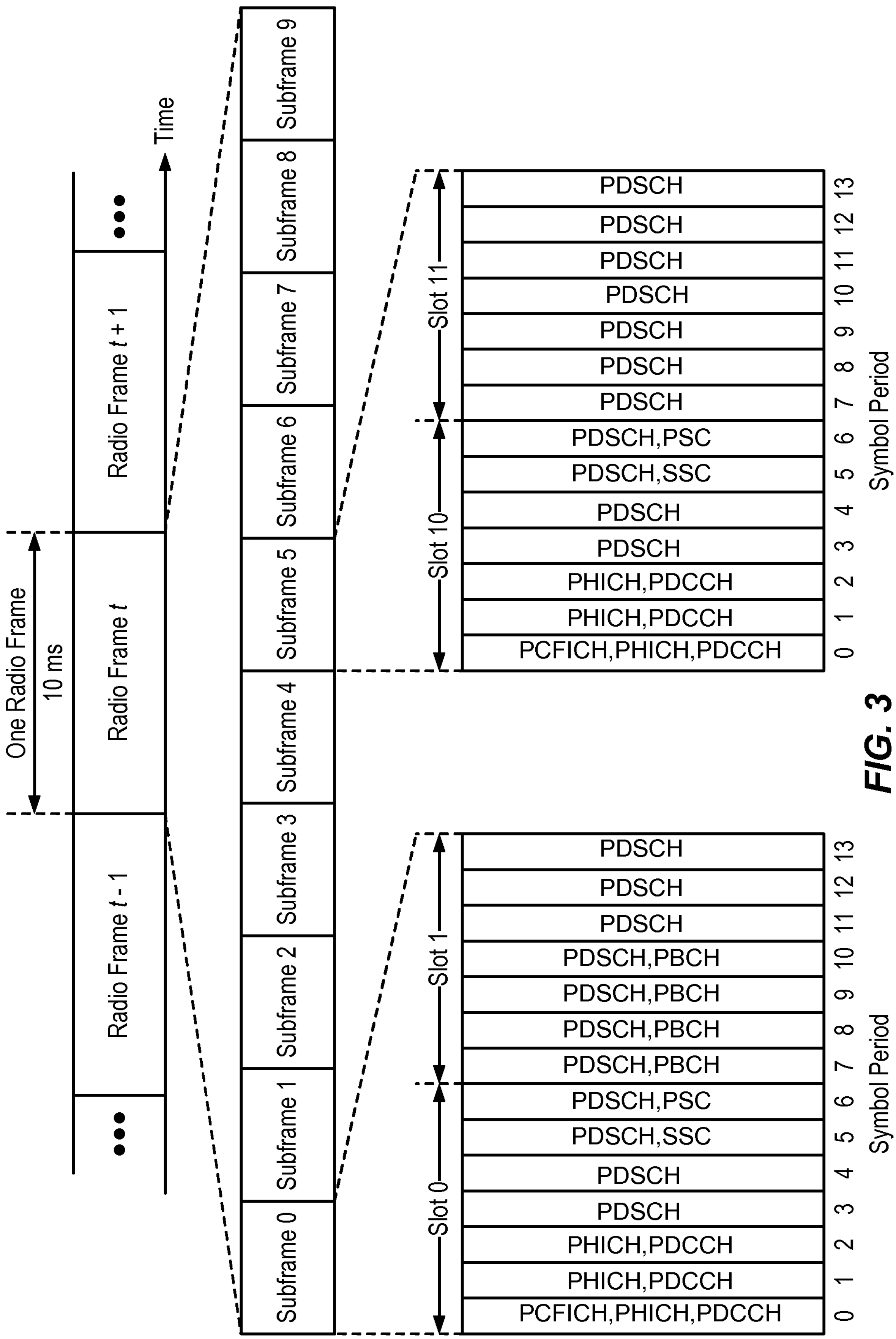
One Radio Frame
10 ms
Time
Radio Frame t - 1
Radio Frame t
Radio Frame t + 1
Subframe 0
Subframe 1
Subframe 2
Subframe 3
Subframe 4
Subframe 5
Subframe 6
Subframe 7
Subframe 8
Subframe 9
Slot 0
Slot 1
Slot 10
Slot 11
PCFICH,PHICH,PDCCH
PHICH,PDCCH
PHICH,PDCCH
PDSCH
PDSCH
PDSCH,SSC
PDSCH,PSC
PDSCH,PBCH
PDSCH,PBCH
PDSCH,PBCH
PDSCH,PBCH
PDSCH
PDSCH
PDSCH
PCFICH,PHICH,PDCCH
PHICH,PDCCH
PHICH,PDCCH
PDSCH
PDSCH
PDSCH,SSC
PDSCH,PSC
PDSCH
PDSCH
PDSCH
PDSCH
PDSCH
PDSCH
PDSCH
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Symbol Period

FIG. 3

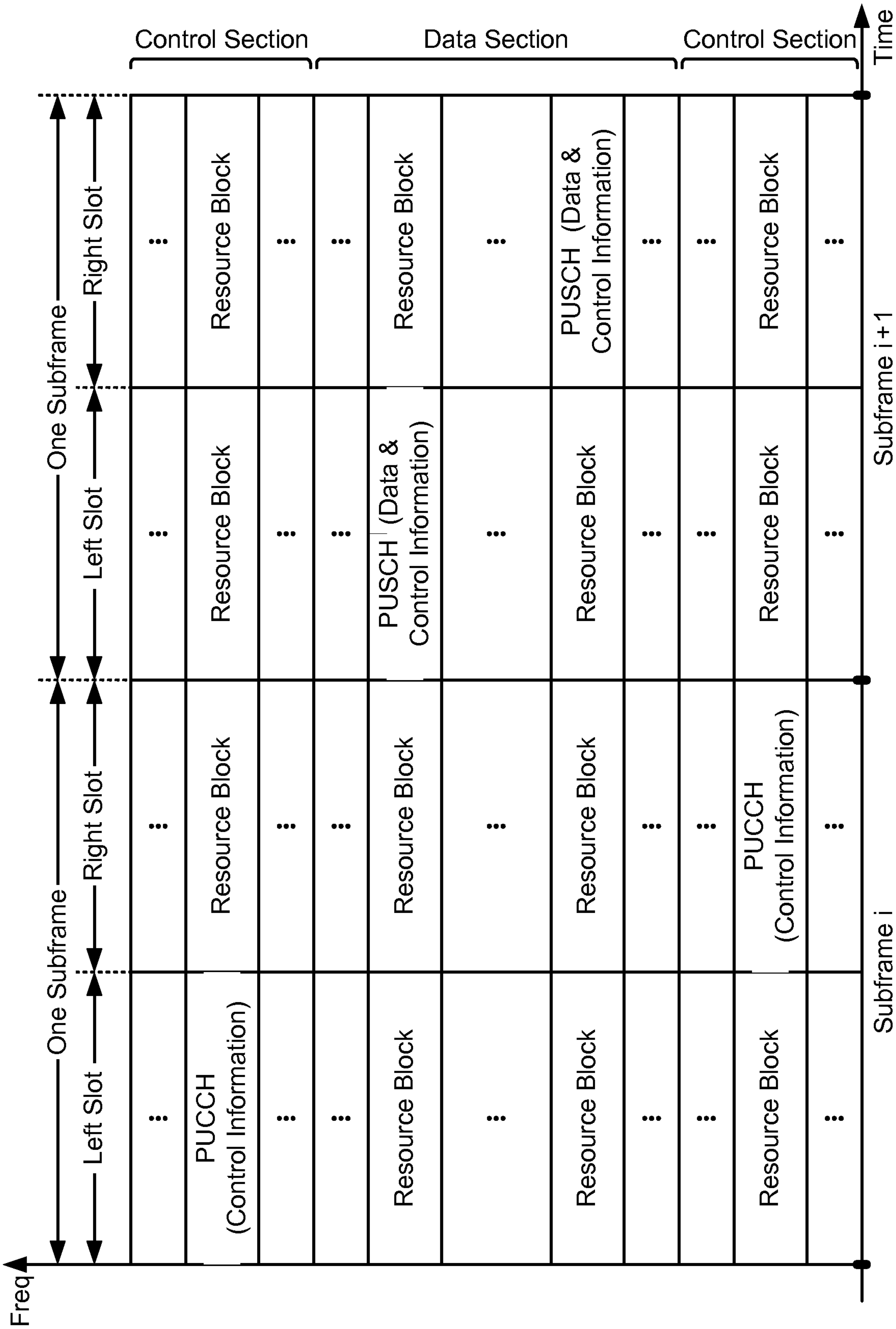
Control Section
Data Section
Control Section
Time
Freq
One Subframe
One Subframe
Left Slot
Right Slot
Left Slot
Right Slot
Resource Block
PUCCH (Control Information)
PUSCH (Data & Control Information)
Subframe i
Subframe i+1

FIG. 4

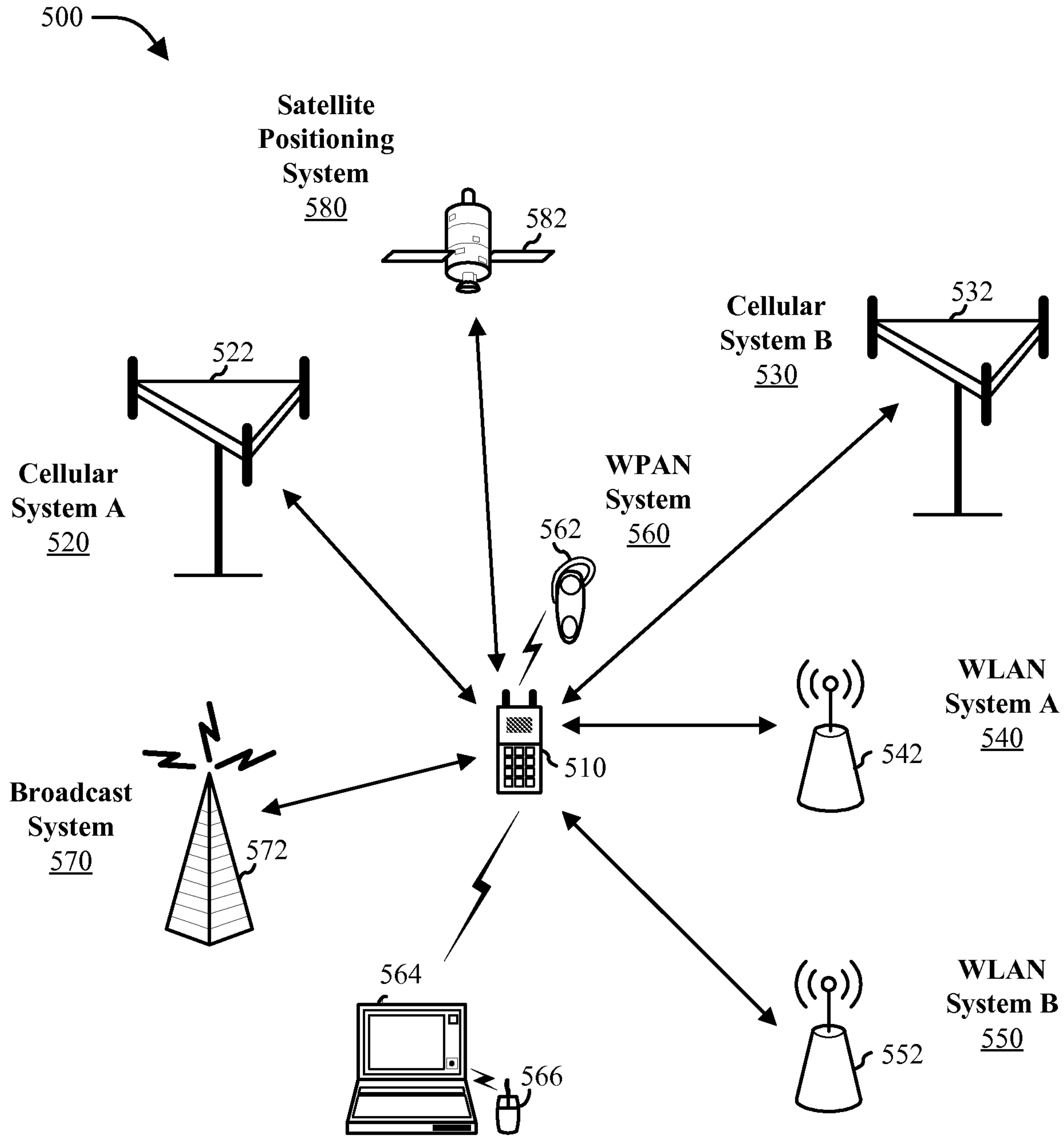
500
Satellite
Positioning
System
580
582
Cellular
System B
530
532
522
Cellular
System A
520
WPAN
System
560
562
WLAN
System A
540
542
510
Broadcast
System
570
572
564
566
WLAN
System B
550
552

FIG. 5

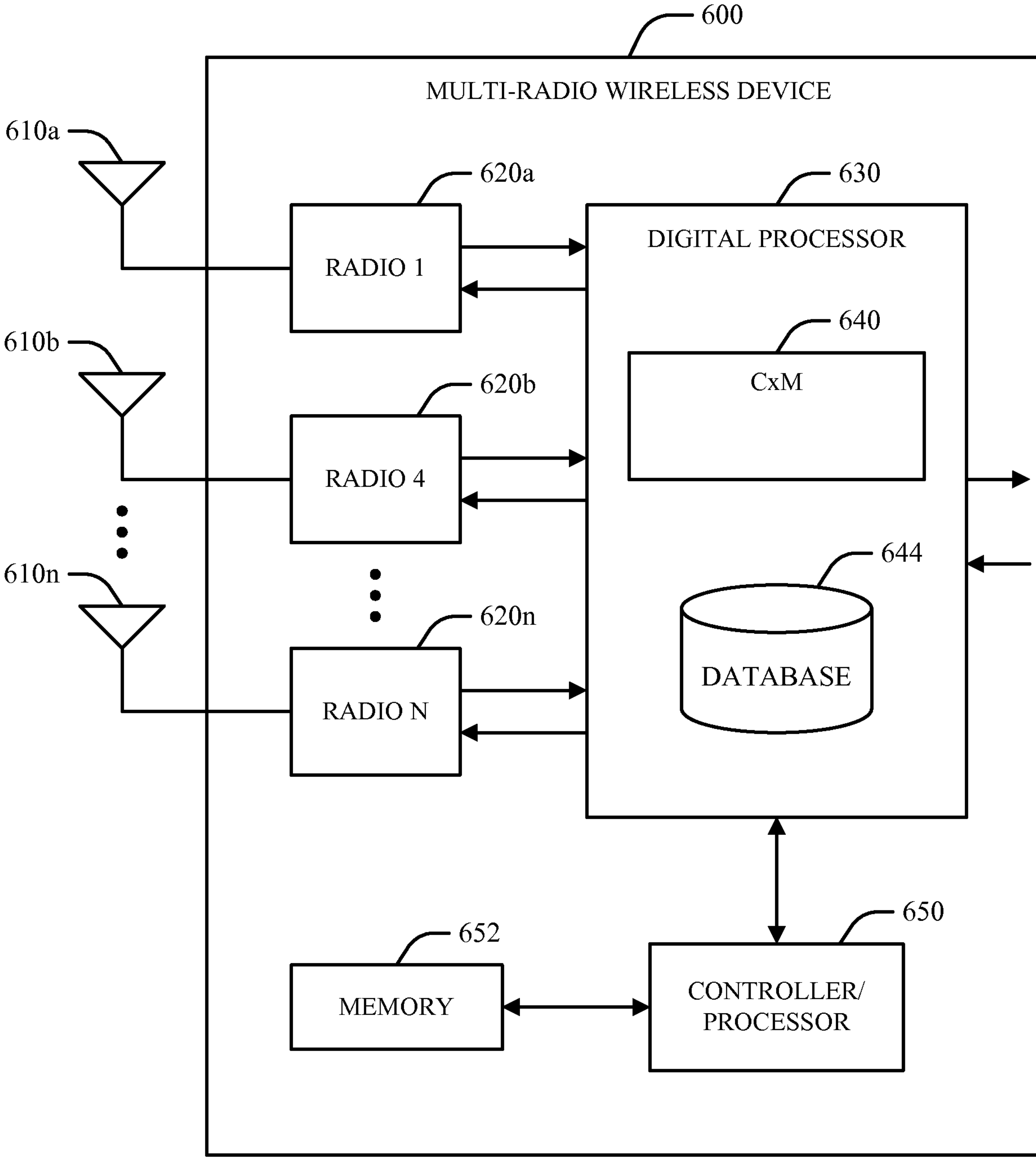
600
MULTI-RADIO WIRELESS DEVICE
610a
620a
630
RADIO 1
DIGITAL PROCESSOR
610b
640
620b
CxM
RADIO 4
644
610n
620n
DATABASE
RADIO N
650
652
MEMORY
CONTROLLER/
PROCESSOR

FIG. 6

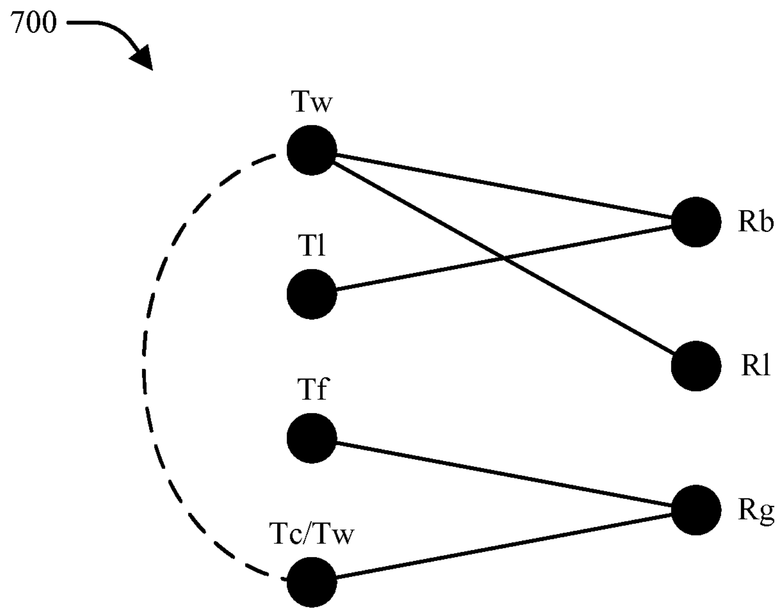
700
Tw
Tl
Tf
Tc/Tw
Rb
Rl
Rg

FIG. 7

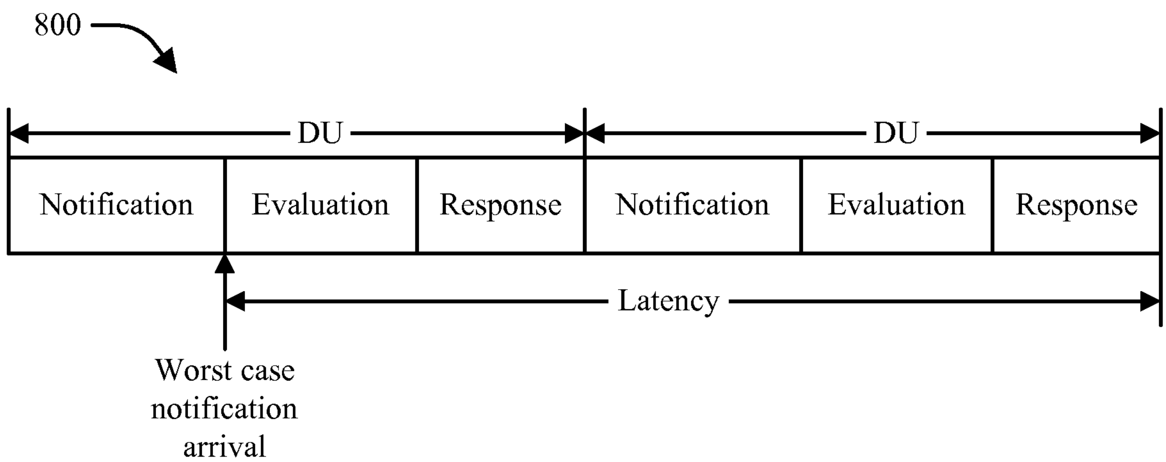
800
DU
DU
Notification
Evaluation
Response
Notification
Evaluation
Response
Latency
Worst case notification arrival

FIG. 8

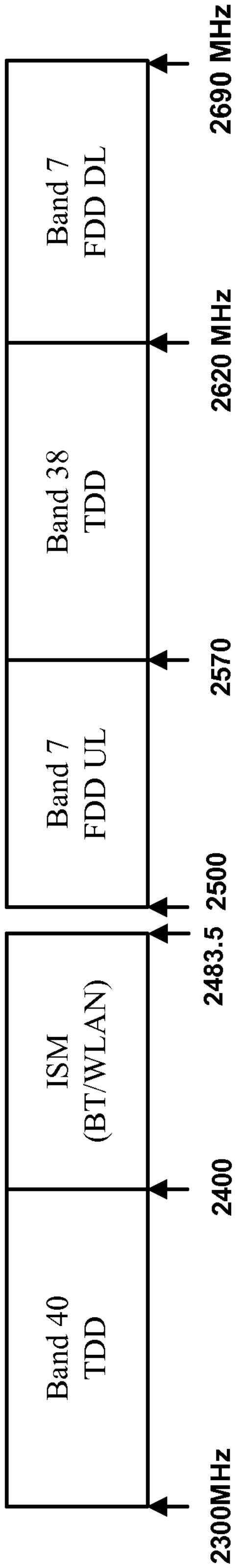
Band 40
TDD
ISM
(BT/WLAN)
Band 7
FDD UL
Band 38
TDD
Band 7
FDD DL
2300MHz
2400
2483.5
2500
2570
2620 MHz
2690 MHz

FIG. 9

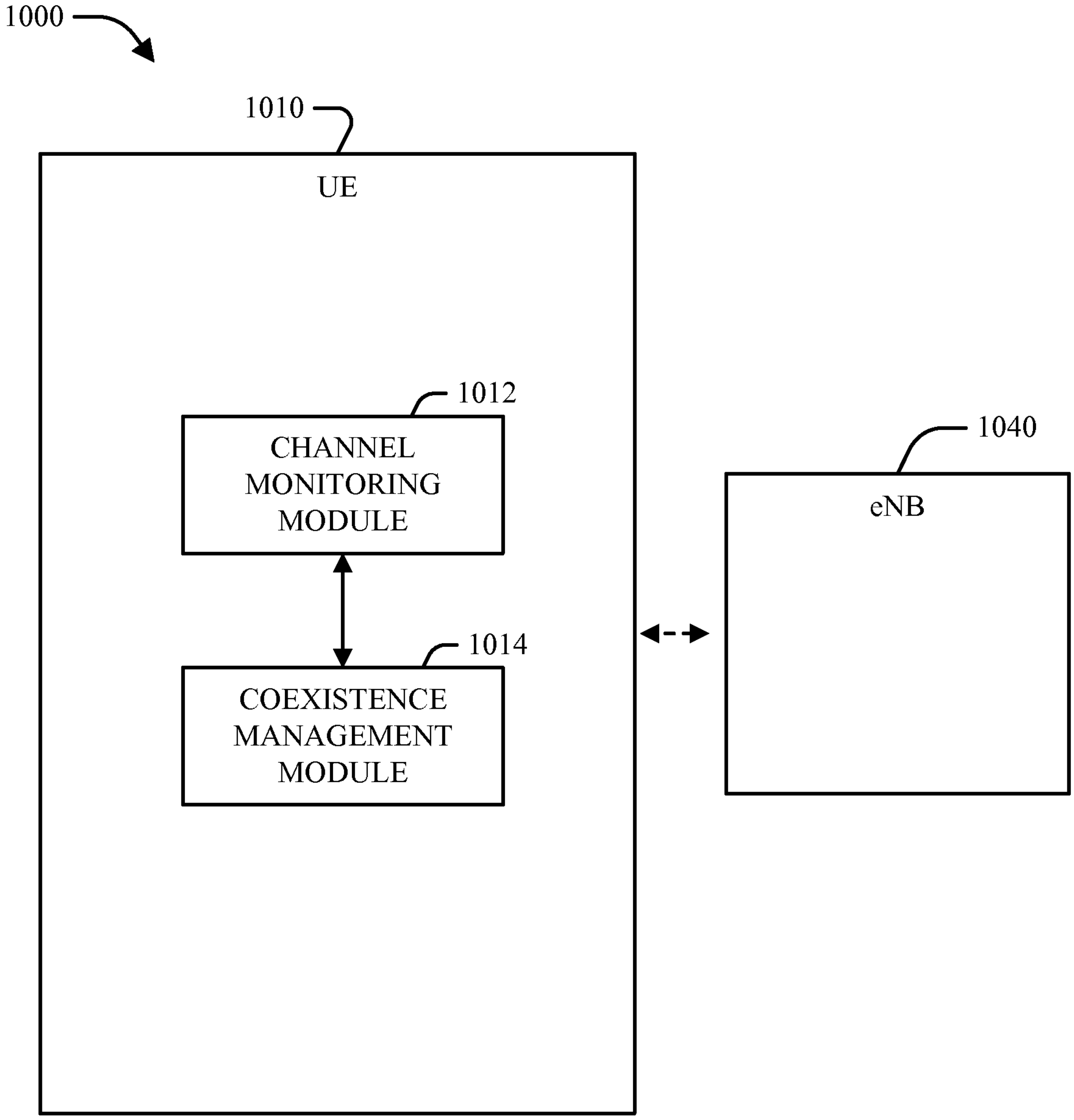
1000
1010
UE
1012
CHANNEL MONITORING MODULE
1014
COEXISTENCE MANAGEMENT MODULE
1040
eNB

FIG. 10

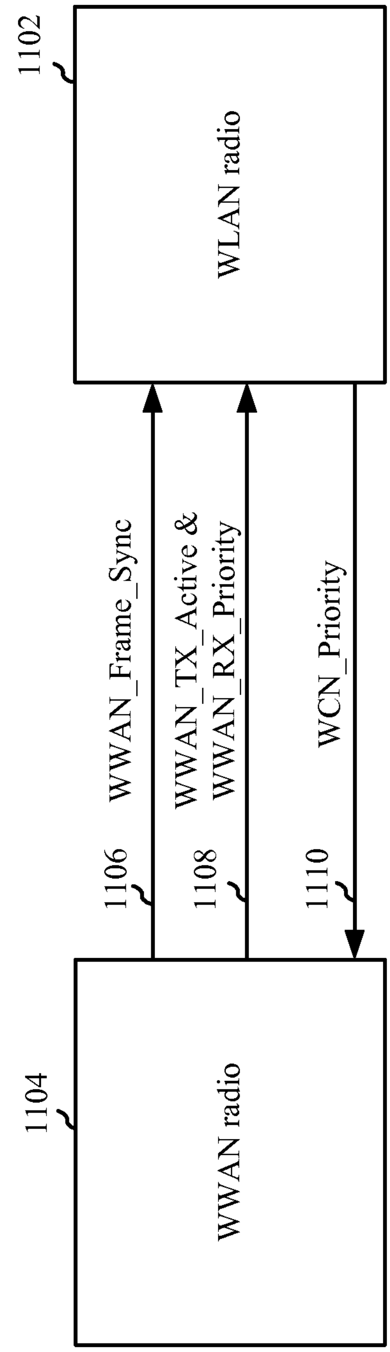
1102
WLAN radio
WWAN_Frame_Sync
WWAN_TX_Active &
WWAN_RX_Priority
WCN_Priority
1106
1108
1110
1104
WWAN radio

FIG. 11

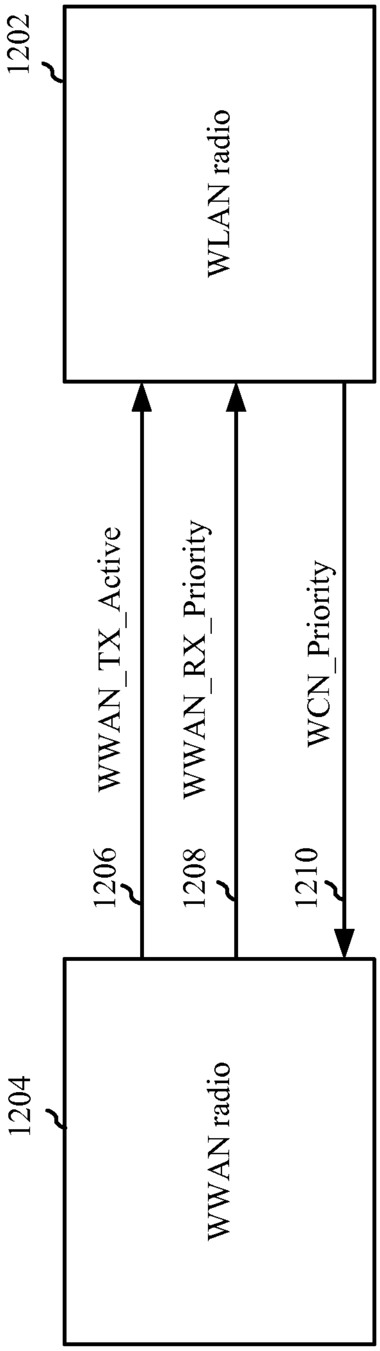
1202
WLAN radio
WWAN_TX_Active
WWAN_RX_Priority
WCN_Priority
1206
1208
1210
1204
WWAN radio

FIG. 12

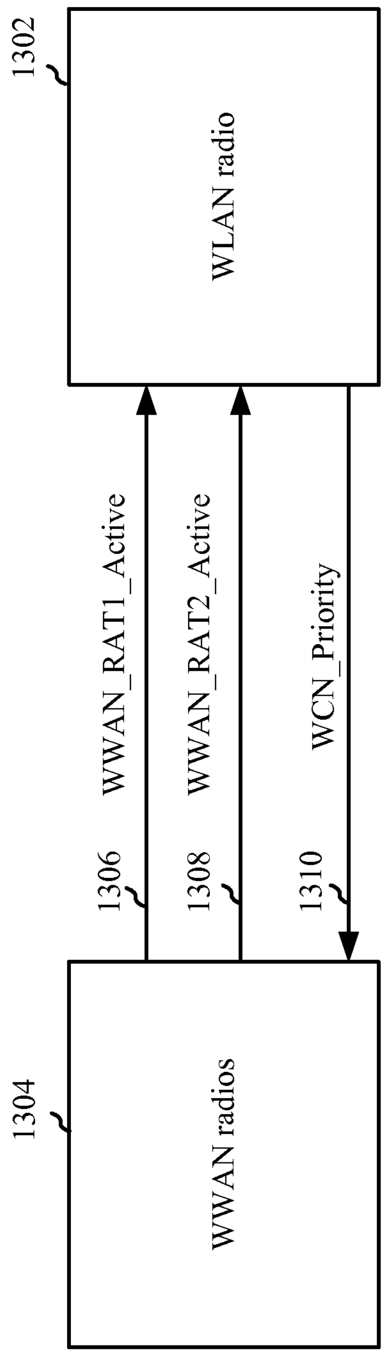
1302
WLAN radio
WWAN_RAT1_Active
WWAN_RAT2_Active
WCN_Priority
1306
1308
1310
1304
WWAN radios

FIG. 13

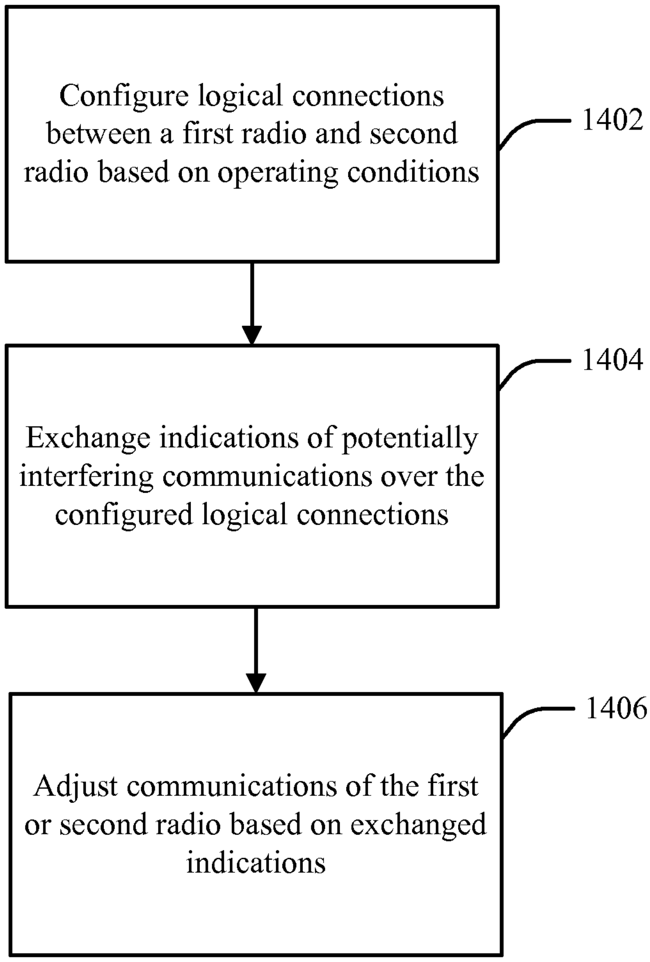
Configure logical connections between a first radio and second radio based on operating conditions
1402
Exchange indications of potentially interfering communications over the configured logical connections
1404
Adjust communications of the first or second radio based on exchanged indications
1406

FIG. 14

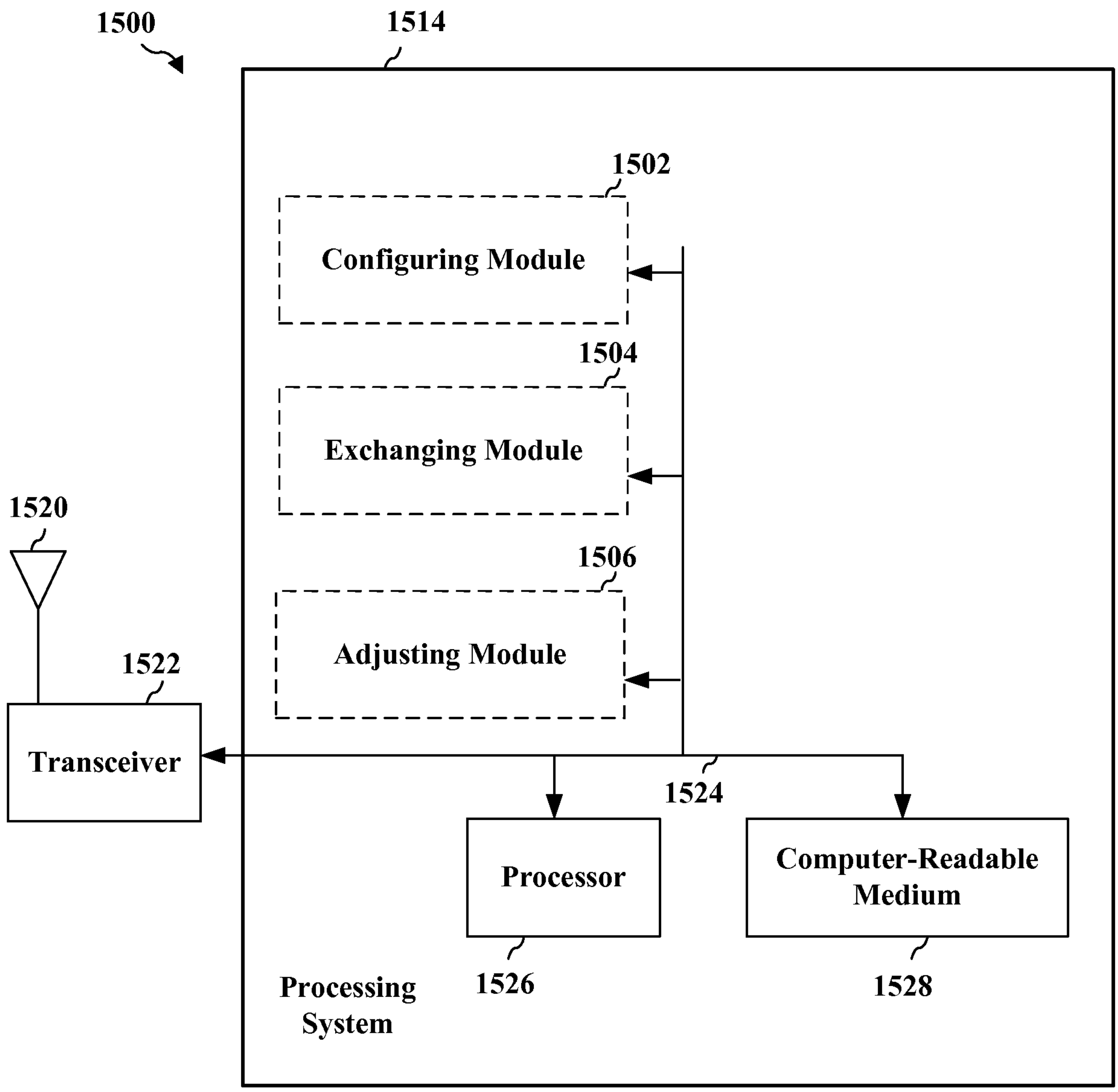
1500
1514
1502
Configuring Module
1504
Exchanging Module
1506
Adjusting Module
1520
1522
Transceiver
1524
Processor
Computer-Readable Medium
1526
1528
Processing System

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/024458

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W16/14 H04W72/08 H04W72/12
ADD. H04W88/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/304685 A1 (WIETFELDT RICHARD D [US] ET AL) 2 December 2010 (2010-12-02) paragraphs [0003], [0005] - [0008], [0024] - [0043], [0064] - [0117], [0120], [0121], [0136] - [0139]; table 1; figures 1-15 -----	1-20
X	US 2010/331029 A1 (LINSKY JOEL B [US] ET AL) 30 December 2010 (2010-12-30) paragraphs [0005] - [0016], [0032] - [0094]; figures 1-16 -----	1-20
X	US 2007/099567 A1 (CHEN CAMILLE [US] ET AL) 3 May 2007 (2007-05-03) paragraphs [0003], [0011] - [0059]; figures 1-6 -----	1-20
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 May 2013	05/06/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Jaster, Nicole

1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/024458

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Study on signalling and procedure for interference avoidance for in-device coexistence (Release 11)", 3GPP STANDARD; 3GPP TR 36.816, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG2, no. V11.2.0, 22 December 2011 (2011-12-22), pages 1-44, XP050555147, [retrieved on 2011-12-22]	1,4-13, 16-20
A	sections 3.1, 4, 5, A.1.3, A.2.2, B.1.1, B.1.2, B.2; figures 4.1-1, A.2.2-1	2,3,14, 15

X	US 2009/054009 A1 (YANG XUE [US] ET AL) 26 February 2009 (2009-02-26)	1-4, 6-16, 18-20
A	paragraphs [0003], [0004], [0020] - [0068], [0070]; figures 1-14	5,17

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/024458

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010304685 A1	02-12-2010	CN 102450088 A	09-05-2012
		CN 102450089 A	09-05-2012
		EP 2438792 A1	11-04-2012
		EP 2438793 A1	11-04-2012
		JP 2012529230 A	15-11-2012
		JP 2012529231 A	15-11-2012
		KR 20120023175 A	12-03-2012
		KR 20120026122 A	16-03-2012
		TW 201116142 A	01-05-2011
		US 2010304685 A1	02-12-2010
		US 2010304770 A1	02-12-2010
		WO 2010141448 A1	09-12-2010
		WO 2010141454 A1	09-12-2010
US 2010331029 A1	30-12-2010	CN 102474726 A	23-05-2012
		EP 2449805 A1	09-05-2012
		JP 2012532498 A	13-12-2012
		KR 20120035202 A	13-04-2012
		TW 201127132 A	01-08-2011
		US 2010331029 A1	30-12-2010
		WO 2011008556 A1	20-01-2011
US 2007099567 A1	03-05-2007	CN 101300870 A	05-11-2008
		EP 1943851 A2	16-07-2008
		JP 2009514433 A	02-04-2009
		JP 2012100278 A	24-05-2012
		US 2007099567 A1	03-05-2007
		WO 2007053691 A2	10-05-2007
US 2009054009 A1	26-02-2009	NONE	